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The Economics, Performance, and Sustainability of Internally Cured Concrete, Part 3

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WEB SESSIONS

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WEB SESSIONS

Early-Age Autogenous Effects in Internally Cured Concrete and Mortar

The Economics, Performance, and Sustainability of Internally Cured Concrete

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THE UNIVERSITY of TENNESSEE CHATTANOOGA
AUBURN UNIVERSITY

Presentation Objectives

1. Evaluate the effect of IC and w/c on the development of ***stress*** and ***internal relative humidity.***
2. Evaluate the effect of IC and w/c on ***autogenous shrinkage*** development in ***concrete*** and ***mortar***.

Outline

- Stress Development Mechanisms
- Testing Equipment
- Experimental Work
- Results
- Conclusions

Stress Development Mechanisms

Why Does Concrete Crack?

Restraint + Volume Change = Stress

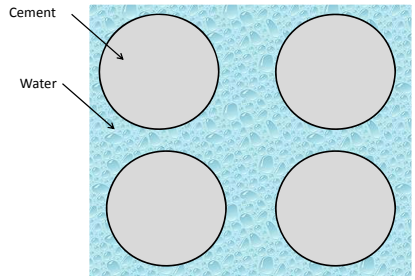
Cracking Occurs When Tensile Stress Exceeds Tensile Capacity

Stress Development Mechanisms

- Early-Age Volume Change Occurs Because
  - Thermal effects
    - Temperature changes due to hydration
    - Coefficient of thermal expansion
  - Decrease of internal relative humidity
    - Drying due to atmospheric conditions
    - Self desiccation (autogenous shrinkage)

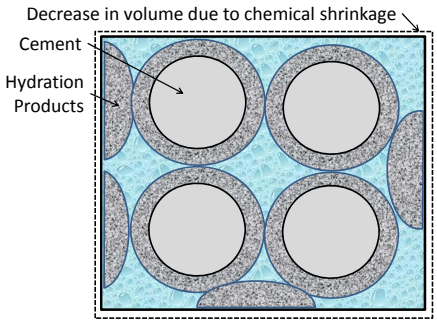
Self-Desiccation

t=0, water meets cement



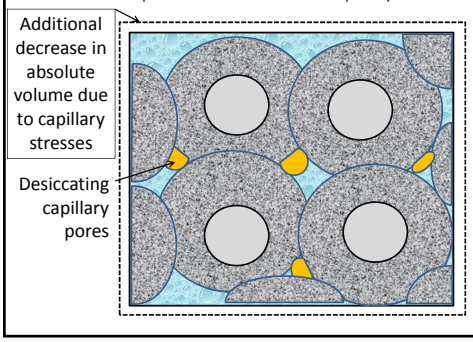
Self-Desiccation

t=initial set, hydration products form skeleton



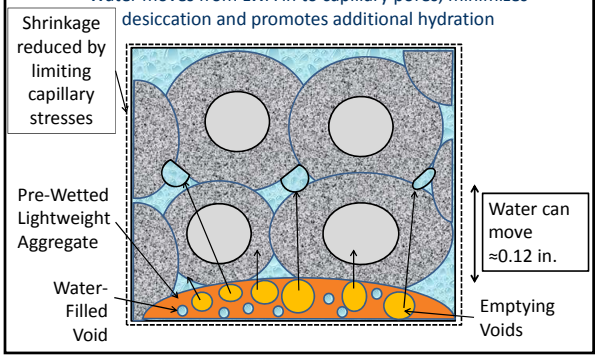
Self-Desiccation

t=after set, hydration continues and cement consumes capillary pore water and induce capillary stresses



Self-Desiccation?

Water moves from LWA in to capillary pores, minimizes desiccation and promotes additional hydration



Internal Curing Mechanisms

- Why Use Lightweight Aggregate?
  - When batched in the prewetted state, LWA has internal water stored in its pores
    - This water promotes hydration ⇒ internal curing
  - Use of saturated lightweight aggregates may alleviate capillary stresses, thus reducing autogenous shrinkage

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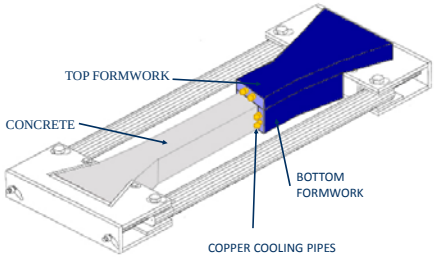
Test Equipment: Stress Development

Rigid Cracking Frame

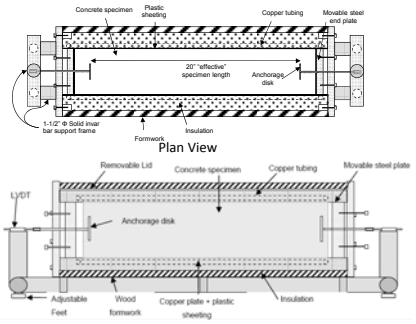


Test Equipment: Stress Development

Rigid Cracking Frames

Testing Equipment: Free Shrinkage

Free Shrinkage Frame

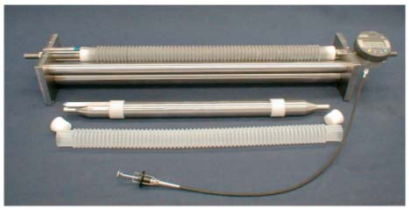


Testing Equipment: Free Shrinkage

Free Shrinkage Frame

Testing Equipment: Autogenous Strain

- Autogenous strain of mortar was measured by the corrugated tube method (ASTM C 1698-09)



Outline

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Experimental Work

Each concrete mixture was tested:

- Restrained Stress Development - Isothermal (73 °)
  - Rigid Cracking Frame
- Free-Shrinkage – Isothermal (73°F)
  - Concrete: Free-Shrinkage Frame
  - Mortar: Corrugated Tube Method ~~-~~ Sieved Mortar
- Internal Relative Humidity – Isothermal (73°)
  - Embedded RH Sensors
- Mechanical Properties
  - Matched Cured to Modeled Temperature Profile

Experimental Work

- Mixtures tested:
  - Control mixtures
    - w/c = 0.42, 0.36, and 0.30
    - Slump: 3 to 5 in.
    - Air Content: 4.5 to 6.5 %
    - Aggregates: siliceous river gravel and natural sand
  - Internal curing mixtures
    - Same w/c, slump, air content, and normal weight aggregates
    - Achieve an equilibrium density greater than 135 pcf
    - Use Bentz method for lightweight aggregate proportioning

Mixture Proportions

Item	0.42 RG	0.42 Shale IC	0.42 Clay IC	0.42 Slate IC
Water Content (lb/yd^3)	260	260	260	260
Cement Content (lb/yd^3)	620	620	620	620
SSD Normalweight Coarse Aggregate (lb/yd^3)	1,761	1,761	1,761	1,761
SSD Normalweight Fine Aggregate (lb/yd^3)	1,210	878	878	818
SD Shale Lightweight Fine Aggregate (lb/yd^3)	0	230	0	0
SD Clay Lightweight Maximizer (lb/yd^3)	0	0	230	0
SD Slate Lightweight Fine Aggregate (lb/yd^3)	0	0	0	276
Target Total Air Content (%)	5.5	5.5	5.5	5.5
Water-cement ratio (w/c)	0.42	0.42	0.42	0.42
Internal Curing Water (lb/yd^3)	0	36	33	22

Mixture Proportions

Item	0.36	0.36 ICM	0.36 ICH	0.30	0.30 ICM	0.30 ICH
Water Content (lb/yd^3)	238	238	238	218	218	218
Cement Content (lb/yd^3)	677	677	677	738	738	738
No. 67 River Gravel (SSD)(lb/yd^3)	1761	1761	1761	1761	1761	1761
TXI Shale Fine Aggregate (SD) (lb/yd^3)	0	184	275	0	188	253
Natural Sand (SSD) (lb/yd^3)	1210	956	823	1210	940	867
Target Air (%)	5.5	5.5	5.5	5.5	5.5	5.5
w/cm	0.36	0.36	0.36	0.3	0.3	0.3
Internal Curing Water (lb/yd^3)	0	31	46	0	32	42

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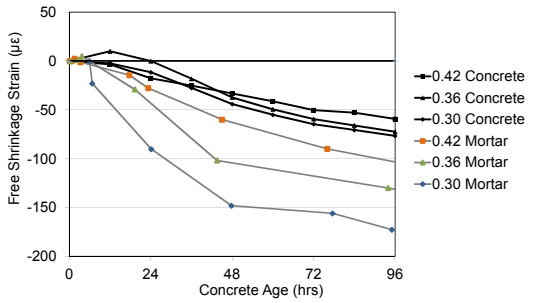
Results
Autogenous Strain: Concrete vs. Mortar



Results
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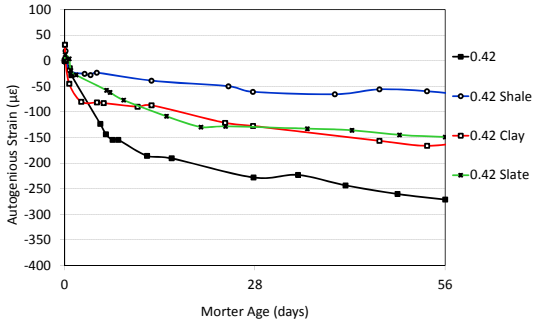
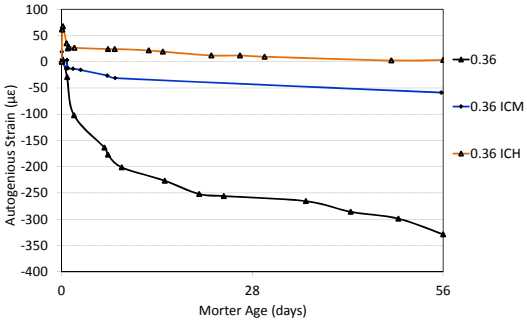
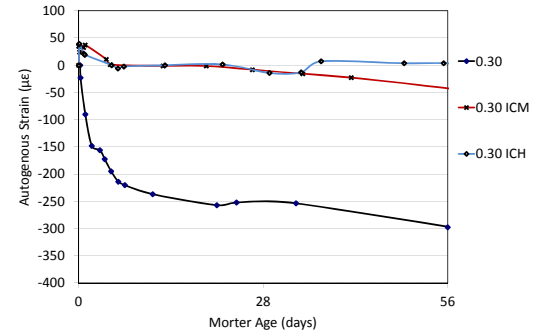


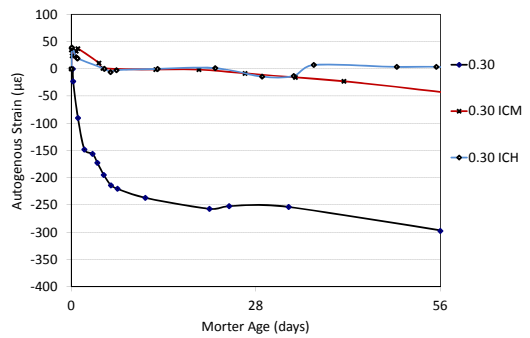
Results
Autogenous Strain: w/c = 0.36



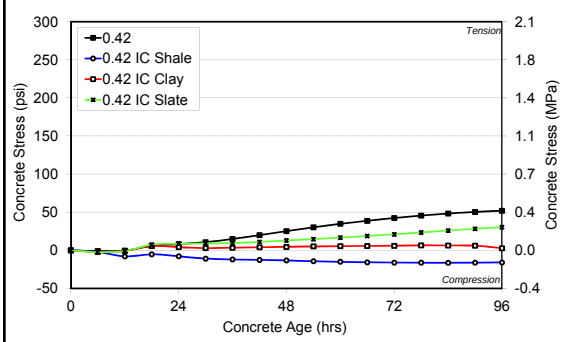
Results
Autogenous Strain: w/c = 0.30



Results
Autogenous Strain: w/c = 0.30



Results
Isothermal Stress Development: w/c = 0.42



Results
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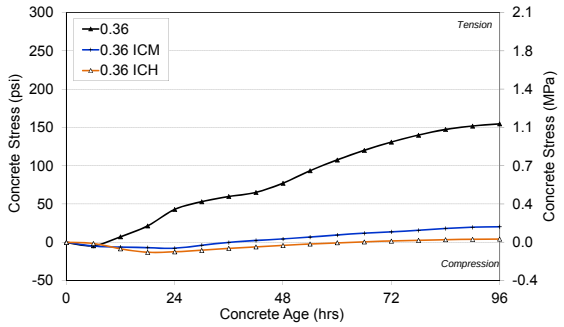
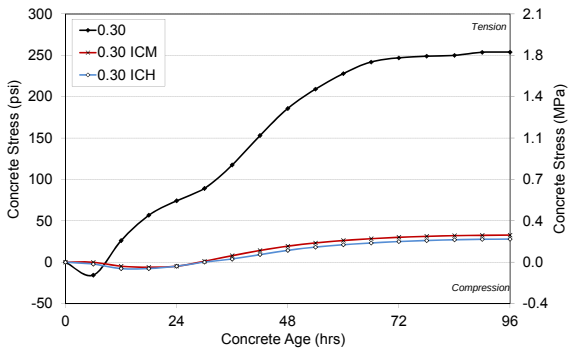
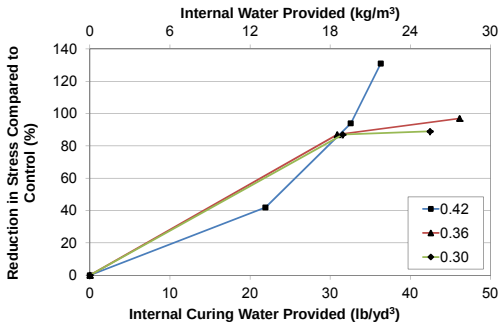


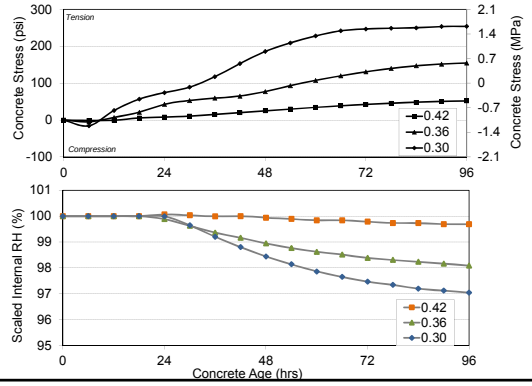
Results
Isothermal Stress Development: w/c = 0.30



Results
Isothermal Stress Development



Results
Internal Relative Humidity



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Conclusions

- Mortar has a ***greater*** autogenous strain than that of concrete, due to the restraint provided by coarse aggregate.
- As the w/c ***decreases***, autogenous stress and strain ***increases***.
- Use of prewetted lightweight aggregates ***reduces*** or ***eliminates*** the stress development and strain caused by autogenous shrinkage.

Thank You For Your Time!

Questions?

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